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Establishment of sub-µm structured polymer surfaces texture using a non-conventional approach

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Abstract

Biotechnology and related medical diagnostic applications have recently shown a high grow potential. Replication of micro and nano structures is the key technology in the bio-medical field. This paper describes a process chain based on the creation of sub-µm structures via anodizing of aluminium, electroforming of a tool insert based on the obtained porous structure and finally polymer replication. Optimisations of the injection moulding process parameters allowed reproducing the features of the nickel master on a polymer substrate. Experimental results indicate the possibility of manufacturing sub-µm geometries by injection moulding of cyclic olefin co-polymer (COC) and polycarbonate (PC).

1 Introduction

Preparations of periodic nanometre features can affect physical and optical properties of the surface in an extraordinary way [1, 2]. Since sub-µm feature details with ultra-low tolerances have to be manufactured, these structures are usually fabricated using clean room technologies or direct ultra precision machining procedures. Methods such as e-beam lithography and nano imprinting lithography [3, 4] have high manufacturing cost and a low throughput. Moreover it has also been difficult to manufacture large areas with the same quality of replicated micro and nano geometries. The current study present a possible solution to the limitations related to the previously mentioned fabrication methods. Hence, the capability of different surface treatment methods of creating micro and nano structured adaptable mould inserts for subsequent polymer replication by injection moulding is investigated.

2 Experimental set up

In order to achieve a more attractive oxide film on the samples surface, mechanical (Figure 1-1) and electro polishing (Figure 1-2) operations were made before anodizing the Al 99,5%. In between these two surface preparation steps the aluminium substrates were annealed below the melting point to obtain a larger grain size and to eliminate residual stresses from previous manufacturing operations. A thin oxide layer was formed on the surface of the Al plates, by anodizing them in a acid electrolyte (Figure 1-3) at either 0°C or 10°C. The electrochemical process enabled the fabrication a compact pore structure of alumina. The oxide layer was than dissolved (Figure 1-4) in order to expose the pseudo hexagonal lattice structure to be later replicated by nickel deposition (Figure 1-5). The first thin nickel layer was deposited by physical vapour deposition (PVD) to make the deposition of a thicker nickel layer easier and to protect the obtained nano structures on the aluminium samples from corrosion. The nickel electroplating process parameters were optimized to avoid potential problems such as high surface roughness, pitting, poor adhesion and high internal residual stresses. Once the aluminium substrates were dissolved and the nickel master

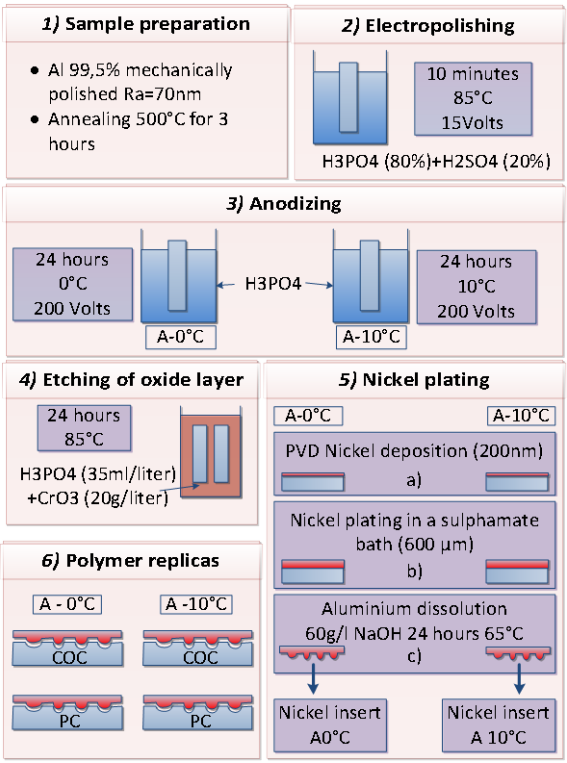

Figure 1: process chain to create micro and nano structures on polymers.

accomplished, sub-µm structured polymer replicas of 30x80mm^2 were produced by means of the injection moulding process (Figure 1-6).

3 Surface replication

Quality control of the different process chain steps was carried out in terms of features detail dimensions. In this regard, due to the large sub-µm structured area on the mould insert, exact re-location of measured area was not possible. The degree of replication among the different process chain stages could not be determined by calculating the aspect ratio of identified replicated structures. Therefore the analysis was based on the evaluation of surface amplitude roughness parameters in Figure 2.

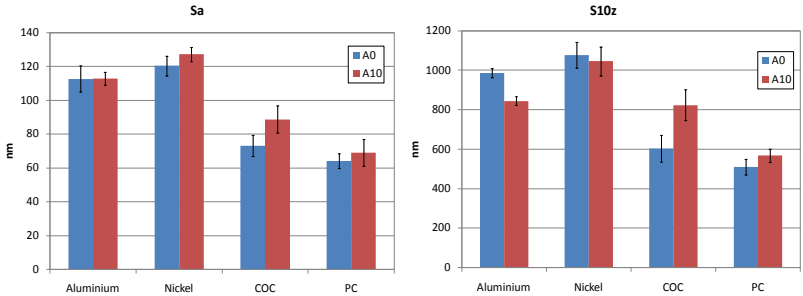

Figure 2: Replication assessment through amplitude parameters evaluation of the different replication steps (error bars indicate 1σ average standard deviation).

Figure 2 depicts roughness values measured on approximately the same spots of the different samples. Evaluation areas of 25x25µm^2 were scanned with an atomic force microscope (AFM) and later elaborated with commercial software scanning probe image processor (SPIP). The graphs show the limitation of the polymers to completely fill all the sub-µm geometries of the mould insert. Mean values of roughness average Sa decrease from 123±5 nm for the nickel inserts, to 80±7 and 66±6 nm respectively for the replicated geometries on COC and PC substrates. This trend can be observed in Figure 3, where SEM pictures of the surfaces at different process chain steps were taken. The self organized pseudo-hexagonal array (Figure 3, left) can be optimized by adopting a high purity (99.99%) aluminium substrate. Fewer alloying elements in the base material would lead to a more regular and levelled final mould insert surface.

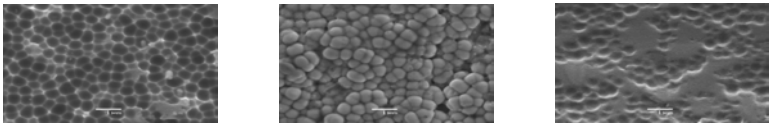

Figure 3: SEM replication steps. Left: aluminium plate after oxide layer dissolution. Centre: nickel inserts. Right: polycarbonate replica.

4 Conclusion

In addition to often expensive and time consuming ultra high-precision technologies, the presented approach based on batch procedures enables fabrication of self assembled sub-µm structures. Further, the use of the injection moulding process for the replication of geometries in the sub-µm range on a large scale substrate offers a low cost process for mass production of macro-components with nano-structured surfaces.

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